BT-1031

Launching of Small Inflated Balloons From Cargo Aircraft

Air Force Cambridge Research Labs.

James C. Payne; Edward Young; Catherine Rice

20 Apr 1973

AFCRL-TR-73-0276
20 APRIL 1973
INSTRUMENTATION PAPERS, NO. 187

AEROSPACE INSTRUMENTATION LABORATORY PROJECT 6665
AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
L. G. HANSCOM FIELD, BEDFORD, MASSACHUSETTS

Launching of Small Inflated Balloons From Cargo Aircraft

JAMES C. PAYNE
EDWARD YOUNG, MAJ, USAF
CATHERINE RICE

AIR FORCE SYSTEMS COMMAND
United States Air Force

Abstract

A simple, inexpensive method has been developed for air-launching constant-level plastic balloons in rapid succession from a transport-type aircraft. The entire launch system is palletized upon one 24-ft modular airdrop platform; no alterations to the aircraft are needed. The balloon, encased in a nylon bag, is inflated inside the aircraft, and extracted by parachute. The bag then falls away, releasing the balloon and payload. Four regular crew members can inflate and launch several 8-ft diam, polyethylene balloons at 10-min intervals from a C-130 aircraft flying at speeds up to 130 knots and at altitudes up to 10, 000 feet.

Contents

Illustrations

Tables

Launching of Small Inflated Balloons From Cargo Aircraft

1. INTRODUCTION

During April 1968 to December 1969, personnel of the Aerospace Instrumentation Laboratory at the Air Force Cambridge Research Laboratories conducted a series of flight tests to determine the feasibility of launching inflated plastic balloons by direct aerial delivery. The specific goal was to develop an uncomplicated procedure whereby a crew of four minimally trained personnel could inflate and launch a succession of plastic balloons capable of floating at 15, 000 ft with payloads of 6 pounds. The primary consideration was that over-all cost, required mechanical accessories, and preflight preparation time and procedures should be reduced to an absolute minimum.

Very satisfactory, but necessarily complex, systems for air-launching balloons had been developed by this Laboratory more than a decade ago. In 1959, for example, a completely self-contained balloon launch system was developed for fighter aircraft. This bomb-shaped aluminum canister contains an uninflated balloon, its payload, special helium container, parachutes and programmed electromechanical devices to extract, inflate and separate the balloon system from its container. The container falls away on a parachute. Before the era of weather satellites, this device was used to insert a balloon-supported tracking transmitter precisely into the eye of a hurricane (Payne, 1960). It has proved entirely feasible,

(Received for publication 18 April 1973)

also, to air-launch balloons by inflating them through a very long fill line beneath a suitably equipped helicopter (Slaughter, 1965). But air-launching systems of such sophisticated design require considerable preflight planning; furthermore, they are relatively expensive. Modern transport-type aircraft which can accommodate inflated balloons of a useful payload range (5-15 lb at 15,000 to 20,000 ft) provide strong incentive for making direct air-launching of balloons practicable.

Unfortunately, due to buoyancy, large surface area, very low mass and fragile material, the inflated balloon is a highly unlikely candidate for routine aerial delivery (by parachute). Even inside the aircraft, it must be protected from protuberances in the labyrinth of wires and pipes along the walls. The critical factor is the capability of the balloon-parachute system to survive the turbulence which it encounters immediately after extraction from the aircraft. The parachute must provide a sufficiently large drag force to extract the balloon quickly out to a distance behind the aircraft where the air is less turbulent. On the other hand, the balloon material has limited strength; it will fail if subjected to an excessively large extraction force.

In the absence of adequate quantitative data to describe the three-dimensional flow field directly behind a C-130 aircraft, the approach to this investigation was almost entirely experimental. Several types and sizes of parachutes, natural-shaped and cylindrical balloons, and various arrangements for safeguarding the balloon were tested.

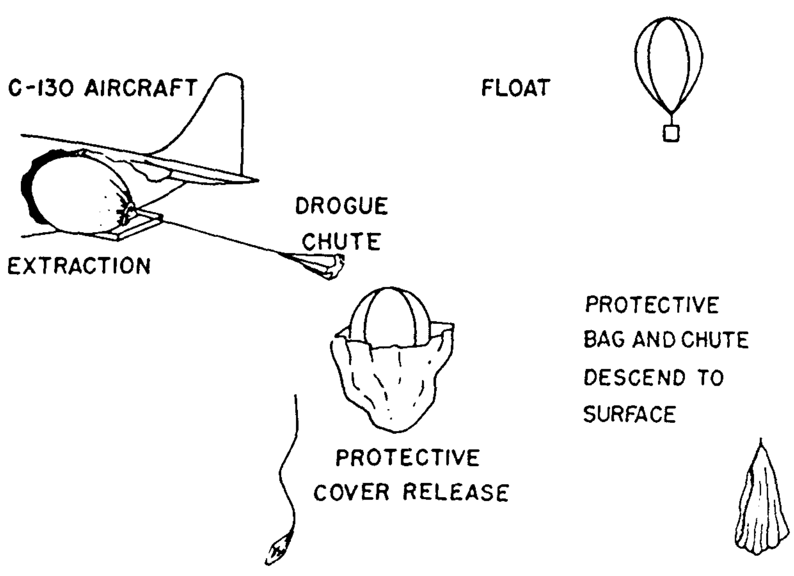

Figure 1. Air Launched Balloon Concept

The procedure which finally evolved is illustrated in Figure 1. The balloon is inflated inside a protective drawstring bag. The drawstring is attached to the parachute drogue line. At a suitable distance beyond the aircraft, a delayed-action line cutter severs the drawstring, opening the bag and releasing the balloon and payload.

A lightweight, solid-state, multifunction timer suitable for the balloon environment was also developed for these tests. Each of the four independent timers can be set for an interval from 0 to 6 hours in 15-min increments.

2. FIRST TEST SERIES: OCTOBER 1968

For the first flight series, a drogue parachute was attached by a 75-ft length of 1500-lb test nylon cord to a simulated payload which, in turn, was attached to the balloon, as in Figure 2a. If the system could survive extraction and withstand the forces in the aircraft wake, the balloon would rise to float altitude (Figures 2b and 2c). The payload included an electromechanical timer which was preset to separate the balloon from the payload, and thus destroy the balloon while it still remained within the boundaries of the test range (Figure 2d).

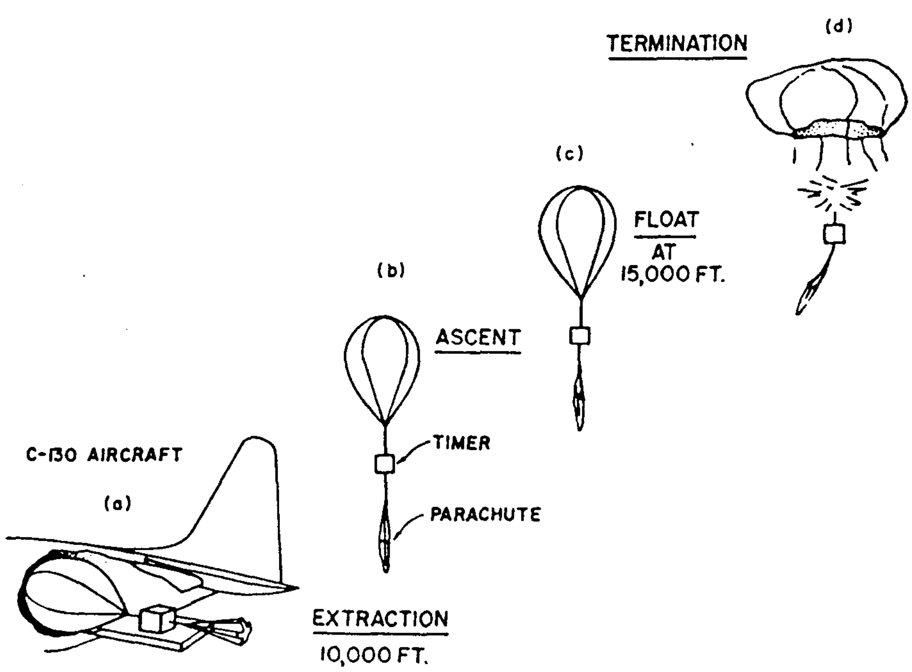

Figure 2. Air Launched Balloon, First Test Series

The balloon envelope was protected from protuberances on the aircraft walls by a free-standing lining formed by mounting a completely enclosable, woven-nylon curtain upon a standard, modular airdrop platform. This "covered-wagon"* obviated any need to alter the aircraft and at the same time, allowed the flight crew free access to the aircraft systems mounted along the walls. A 24-ft modular platform with the rack of helium tanks placed at one end was large enough for the balloon to be completely inflated inside the covered wagon. Thus there was a gain of ready mobility and general convenience in palletizing the entire balloon operation.

Eleven air-launch tests were conducted either at 10,000 ft MSL altitude, with indicated air speed 120 knots, or at 5,000-ft altitude, with 110-knot speed.

2.1 The "Covered Wagon"

According to the original launch plan, just before the balloon was released from the aircraft the covered wagon would be moved aft as far as possible out over the tailgate. However, as a result of the first test this procedure was altered; the covered wagon henceforth was to be positioned just at the edge of the tailgate hinge and not moved during flight. The top of the covered wagon was lengthened by 16 inches; a simple pin release for the balloon restraint line was installed at the aft edge of the covered wagon platform, and an 8-ft platform was placed upon the aircraft tailgate to cover the cargo rollers, providing a smooth surface for the balloon to slide upon. As an additional safeguard, in order to prevent the premature escape of the balloon, removable straps were placed across the aft end of the covered wagon.

2.2 The Parachute

For the first two air-launch attempts the parachute was a 16-inch cross-type which produces a drag force of approximately 19 lb in a 130-knot wind at 10,000-ft MSL altitude. This force proved to be much too small to prevent the balloon's being trapped beneath the aircraft tail. With a 25-inch cross parachute providing approximately twice the drag force, the balloon bounced between the tailgate and the underside of the aircraft tail and eventually failed. Nevertheless, film records show that the 25-inch cross-type parachute was very stable. A flat, circular-type parachute of comparable extraction force proved to be very unstable, and even a 30-inch cross-type parachute did not perform reliably.

---

* In balloon parlance, a "covered wagon" is any portable, tentlike, protective enclosure used for inflating and launching a balloon.

2.3 Drogue Line Rigging

The drogue line was 1500-lb test nylon, 75-ft long, a length which proved sufficient to place the parachute in relatively stable air behind the aircraft.

In an effort to counteract the pronounced tendency of the balloon to be forced up against the underside of the aircraft tail, in addition to increasing the parachute size, a dead weight was added to the drogue line. This weight was cut away from the balloon system by delayed-action (5 sec) line cutters, initiated by a lanyard at the covered wagon during extraction. The best results were obtained with the dead weight placed 20 to 30 feet from the parachute.

2.4 Conclusions

The cross-type parachute deployed and inflated rapidly, and was stable, but it became evident that a much larger horizontal component of drag force was needed to extract the balloon system to a safe launch position, out of the turbulent wake of the aircraft. With its sharply limited load-bearing capacity, however, this relatively small balloon would be destroyed by a large, concentrated snatch force. Therefore, the desirably simple launch system used in the first test series was rejected and a fresh approach taken to the basic problem.

3. NEW CONCEPT

In the next test series, a much larger cross-type parachute would be used. The drogue line, however, would not be attached to the balloon envelope. Instead, the balloon would be tightly encased in a strong fabric cover, or bag, and the drogue line attached to the bag.

At this stage in the experiments, it was being theorized that the bag should absorb the force of extraction, provided that its surface is taut when the balloon is fully inflated. The bag should provide the structural strength to contain the balloon, whereas the balloon provides the gas barrier. The surface area of the balloon must be greater than that of the bag in order that no load be placed on the balloon material. Again, the bag should protect the balloon from environmental damage both inside and just outside the aircraft.

After the balloon is safely beyond the aircraft, line cutters would automatically sever the drawstring and the bag should fall open to set free the balloon and its payload. As scheduled, a preset, timer-governed relay would cause the payload to be cut away from the balloon and thus terminate the flight. The pallet base of the covered wagon would be retained, but the curtain omitted.

4. SECOND TEST SERIES: DECEMBER 1968

The first model protective bag for the 200-cu ft balloon was formed from a flat circle of nylon cloth with grommets inserted close to its outer circumference (Figure 3). In tying the bag an ample length of drawstring was allowed between adjacent grommets and the slack was taken up by looping it into a chain. The chain should immediately slip out when the drawstring is cut and so promote a rapid, smooth bag opening. Eight tests were made using the flat circular bag.

The 6.5-ft parachute was adequate and the protective-bag concept proved to be basically sound, but the bag design required further modification to ensure reliable and rapid opening. Location of the payload relative to the bag also needed further study.

Figure 3. Flat-circular Bag, December 1968 Series

5. THIRD TEST SERIES: FEBRUARY 1969

5.1 Modified Flat-Circular Bag

The grommets to guide the drawstring were replaced by 24 (1-inch) D-rings suspended on fabric tabs sewn on the outside of the bag. These rings were set farther back from the rim of the bag for tighter fit to the balloon (Figure 4).

A balloon enclosed in the new bag survived a drop test from the roof of a two-story building. Next it was hoisted 200 feet up on a tethered balloon and released (Figure 5). The bag opened rapidly and smoothly; the balloon emerged and ascended without incident.

For the flight tests, a cylindrical extension shaped to fit the payload was added to the base of the bag (Figure 6). The modified flat-circular bag was used on six air-launches of a natural-shaped, 200-cu ft polyethylene balloon, with a 4-lb 5 oz payload, and a 5-ft cross-type parachute. No weight was added to the balloon or drogue line.

5.2 Results

The test results are summarized in Table 1. In each case the parachute performance was satisfactory, the bag opened smoothly, and the natural-shaped balloon was safely launched. Three of the balloons which were successfully air-launched had not reached floating altitude within the time set on the automatic termination device.

Figure 4. Flat-circular Bag, February 1969 Series

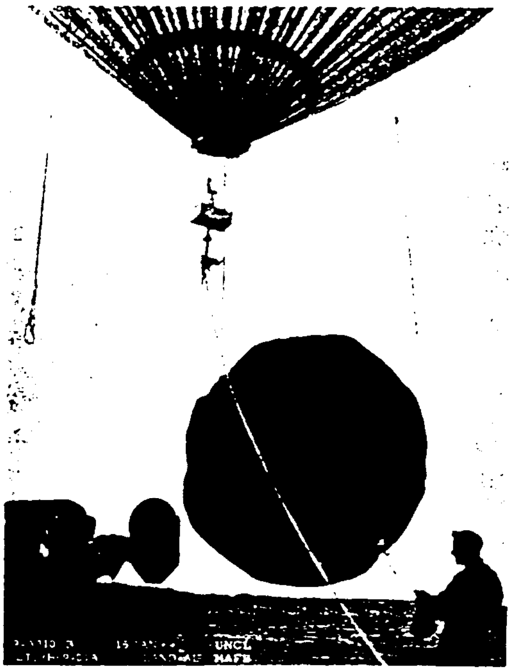

Figure 5. Tethered Balloon Drop Test of Flat-circular Bag

Figure 6. Flat-circular Bag With Cylindrical Extension

Table 1. Third Flight Series, February 1969

Date	Flight Number	Launch Altitude Speed* (Knots)	Termination Altitude (Feet)
2/14	1	110	8,600
	2	110	8,600
	3	110	15,000
	4	110	16,000
	5	125	15,000
	6	125	5,580

*Launch altitude 5,000 ft

5.3 Conclusions

The feasibility of this launch method was demonstrated using the natural-shaped balloon. Plans were formulated to apply the principle to larger, cylindrical balloons which could be accommodated in the same aircraft.

6. FOURTH FLIGHT SERIES: JUNE 1969

6.1 Cylindrical Bag Design

A protective bag for cylindrical balloons was designed from a cylinder of nylon cloth 7.5 ft in diameter and 11 ft long, with one end gathered and sealed to form a closed, hemispherical bottom (Figure 7). To make the bag opening as wide as possible, a flat, circular ring of material, outer diameter 9.65 ft, was attached to the open end of the cylinder (Figure 7). Large D-rings to guide the drawstring were sewn to this bag extension.

Figure 7. Protective Bag for Cylindrical Balloon

6.2 Air Launch Tests

Five launch tests were made with a cylindrical, 8 ft. diam, 1-mil polyethylene balloon, a 15-lb simulated payload, two sizes of parachute, and protective bags made of several different combinations of materials. Details are presented in the flight summaries (Table 2).

Table 2. Flight Summaries, Fourth Flight Series

Test	Protective-bag Materials		Cross-type Parachute (Feet)	Remarks
	Cylinder	Flat-Circular Extension		
1	nylon	cotton-muslin	5	Balloon initially trapped at upper corner of cargo door; eventually released; film revealed hole in top
2	nylon	cotton-muslin	5	Balloon again trapped at upper corner of cargo door; recovered bag showed that muslin had failed
3	335 lb/in nylon	335 lb/in. nylon	7	Parachute satisfactory, bag intact, but balloon burst inside bag during the 10-sec delay prior to line-cutter activation
4	145 lb/in. nylon	335 lb/in. nylon	7	Same as test 3
5	335 lb/in. nylon	145 lb/in. nylon	7	Same as test 3

6.3 Discussion

A 5-ft parachute used in the first two tests provided insufficient extraction force for the larger balloon and heavier bag. By substituting a 7-ft cross chute for the remaining launches, approximately twice the extraction force was obtained.

A muslin bag extension used in the first two trials had been selected for its light weight and low cost—low cost being a primary design consideration. Those tests demonstrated that the muslin was unsatisfactory and nylon materials were substituted for the bag extension. In subsequent tests, the stronger bags remained intact and immediately cleared the aircraft. In each of these tests with the nylon bags, it was determined that the balloon had burst within the bag before the bag opened.

Test 4 was purposely made at low altitude (2, 000 ft) so that the launch procedure could both be observed visually and photographed from ground.

6.4 Conclusions

It was evident that bag should be of all-nylon construction and a 7-ft parachute is required for this system.

The consistent pattern of cylindrical balloon failure within the bag strongly suggested that the excess material in the flat-circular extension allowed the balloon to burst when the balloon-bag combination was subjected to the extraction force and turbulent air.

Once again, personal judgment proved not to be a sufficiently reliable criterion for fully inflating the balloons. A flowmeter, or pressure gage and temperature measurements should be used to determine the proper amount of lifting gas.

Since all of the other preparations can be done in advance, a simple straightforward preparation procedure has evolved from these experiments. This procedure is summarized as follows:

1. Roll out balloon and parachute.
2. Prepare for inflation.
3. Insert cutters in cannons.
4. Install squibs in cannons.
5. Attach payload to balloon end fitting and place in bag.
6. Inflate balloon.
7. Start timer.
8. Start stop watch.
9. Make stray voltage check.
10. Connect timer to squibs.
11. Close bag.
12. Advise the pilot that balloon is ready.
13. Pull safety pins on reefing line cutters.
14. Launch balloon.

7. FIFTH TEST SERIES: DECEMBER 1969

7.1 Modified Cylindrical Bag

To eliminate some of the excess material, the flat-circular extension which formed the mouth of the bag was replaced by a 15° truncated cone, and the D-rings were moved farther back from the edge to provide a tighter fit to the balloon. On the first two trials the balloon was a 1-mil polyethylene, 8-ft cylinder which weighed 3 lb 3 oz, and the payload, including ballast, weighed 15 pounds. An 8-ft cross parachute was used with a 1/4-inch nylon, 2, 000-lb test drogue line.

7.2 Results

Due to overcast at 5, 000 feet, the first test was conducted at 3, 000 ft and 125 knots indicated air-speed. During extraction from the aircraft, the section of the bag near the payload burst. Two other longitudinal failures in the cylindrical section could be traced by matching threads found on the aircraft cargo chute release hook and on the rivets on the underside of the raised cargo door. The balloon itself had one tear along its entire length. The balloon had actually pushed up the top on the covered wagon, exposing a hook mounted in the ceiling of the C-130 aircraft.

To test the assumption that the bag should be pressurized to assume the snatch force load, on the second trial the balloon was purposely inflated to a computed lift of 25.4 lb, and the bag was made tight all around. To protect the bag from catching on the pendulum hook, the covered wagon was pushed aft as far as possible, but once more the bag failed. One tear was found just above the payload and two other tears, on the cylindrical section. From the film record it appeared that the tears were due to failure of the bag material.

The film records of the first two tests show that the parachute becomes inflated just a few feet outside the aircraft, causing quite a substantial snatch force.

On the next two tests stronger, 2-mil polyethelene cylindrical balloons were used. These tests were conducted with the bags purposely slack (not pressurized). The drogue-line length was increased from 80 to 160 ft and a cardboard flap was attached to the aft end of the "covered wagon" to shield the bag from protuberances on the cargo door.

This arrangement worked very well; the balloon was extracted directly through the center of the cargo-door opening (instead of moving to the right rear corner). The additional 80 ft of drogue line was considered to have contributed to this successful launch. Even though it was purposely underinflated, the balloon worked its way out of the bag. It then slowly descended until separated by timer from the payload.

The final test was made at 3, 000 ft with another underinflated (20 pounds lift), 2-mil polyethylene cylinder and the 160-ft drogue line. While being held in the aircraft, awaiting timer-destruct of the previous balloon, the bag became somewhat softer, indicating the possibility of a leaking balloon. This system was launched without difficulty and the balloon worked its way out of the bag, only to descend, owing to loss of gas.

The bag used on this final trial had two nylon-screen "windows" which had been installed to prevent buildup of a negative pressure at the bottom of a tightly fitted bag as the balloon worked its way out of the top. The windows weakened the bag structure, causing splits on both sides of these areas. The balloon also ruptured (about one-third of the distance from the bottom).

One procedural detail was changed for this flight. The drogue parachute and about 140 feet of its line were packed in a parachute bag similar to the one used previously, but enlarged to accommodate the longer line. The conventional shot compartment in this bag was increased from 3 to 5 pounds. (The lead shot gives mass to the bag so that it can be thrown from the aircraft.) The remaining 20 ft length of drogue line was laid loose on the ramp. This proved to be a basic mistake since the weighted bag began to move the balloon before the line and parachute were deployed. As a result, the balloon was exposed to the turbulent air flow before sufficient extraction force could be built up.

The line must be systematically deployed before the balloon moves. On the previous flights this was accomplished by taping the unpacked length of line to the ramp.

8. CONCLUSION

As a result of the February 1969 tests, a convenient, inexpensive method has been developed whereby crew members can inflate and launch a number of inextensible natural-shaped balloons at 10-min intervals from a C-130 aircraft flying at 10, 000 ft at speeds up to 130 knots. This system uses natural-shaped, 1-mil polyethylene balloons which float at 15, 000 ft with 5-lb payloads, the original goal for this investigation. In addition, from the later tests the essential design information has been obtained for extending the system to cylindrical, 2-mil polyethylene balloons large enough to float at 20, 000 ft with a 15-lb payload.

References

Payne, J. (1960) Final Report on the Hurricane Positioning Device Feasibility Study, AD 874-713L.

Slaughter, L. (1965) Balloon Launching from Airplanes and Helicopters, Proc. 1964 AFCRL Scientific Balloon Symposium, AFCRL 65-486, AD 619695.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Air Force Cambridge Research Laboratories (LCB) L. G. Hanscom Field Bedford, Massachusetts 01730	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

LAUNCHING OF SMALL INFLATED BALLOONS FROM CARGO AIRCRAFT

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Scientific. Interim.

5. AUTHOR(S) *(First name, middle initial, last name)*

James C. Payne
Edward Young, Maj, USAF
Catherine Rice

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
20 April 1973	20	2

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) AFCRL-TR-73-0276
b. PROJECT, TASK, WORK UNIT NOS. 66651101	
c. DOD ELEMENT 63404F	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* IP No. 187
d. DOD SUBELEMENT 636000	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
TECH, OTHER	Air Force Cambridge Research Laboratories (LCB) L. G. Hanscom Field Bedford, Massachusetts 01730

13. ABSTRACT

A simple, inexpensive method has been developed for air-launching constant-level plastic balloons in rapid succession from a transport-type aircraft. The entire launch system is palletized upon one 24 ft-modular airdrop platform; no alterations to the aircraft are needed. The balloon, encased in a nylon bag, is inflated inside the aircraft, and extracted by parachute. The bag then falls away, releasing the balloon and payload. Four regular crew members can inflate and launch several 8-ft diam, polyethylene balloons at 10-min intervals from a C-130 aircraft flying at speeds up to 130 knots and at altitudes up to 10,000 feet.

DD FORM 1 NOV 65 1473

Unclassified
Security Classification

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Balloon						
Air launched balloon						
Payload						
Parachute						
Cargo aircraft						

Unclassified

Security Classification